INEEL/CON-98-00224
CONF-980619--

# ELECTRIC VEHICLE FLEET OPERATIONS IN THE UNITED STATES[1]


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## Abstract

The United States Department of Energy (DOE) is actively supporting the development and commercialization of advanced electric vehicles, batteries, and propulsion systems. As part of this effort, the DOE Field Operations Program is performing commercial validation testing of electric vehicles and supporting the development of an electric vehicle infrastructure. These efforts include the evaluation of electric vehicles in baseline performance, accelerated reliability, and fleet operations testing. The baseline performance testing focuses on parameters such as range, acceleration, and battery charging. This testing, performed in conjunction with EV America, has included the baseline performance testing of 16 electric vehicle models from 1994 through 1997. During 1997, the Chevrolet S10 and Ford Ranger electric vehicles were tested. During 1998, several additional electric vehicles from original equipment manufacturers will also be baseline performance tested. This and additional information is made available to the public via the Program's web page (http://ev.inel.gov/sop). In conjunction with industry and other groups, the Program also supports the Infrastructure Working Council in its development of electric vehicle communications, charging, health and safety, and power quality standards. The Field Operations Program continues to support the development of electric vehicles and infrastructure in conjunction with its qualified vehicle test partners: Electric Transportation Applications, and Southern California Edison. The Field Operations Program is managed by the Lockheed Martin Idaho Technologies Company at the Idaho National Engineering and Environmental Laboratory.




## Introduction

During the next several years, utility fleet managers in the United States are required to purchase and use alternative fueled vehicles in their fleets. To support this introduction of electric vehicles into commercial fleets and to facilitate the electric vehicle purchase decision process of fleet managers, the Field Operations Program is documenting the commercial validation of electric vehicles. This paper

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[1] Work supported by the U.S. Department of Energy, Assistant Secretary for Energy Efficiency and Renewable Energy, Under DOE Operations Office Contract DE-AC07-94ID13223.

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## DISCLAIMER

communicates recent and ongoing commercial validation efforts in support of this goal and discusses infrastructure development support by the U.S. Department of Energy (DOE).

The Field Operations Program has two groups of Qualified Vehicle Testers as its partners:

- Southern California Edison (lead organization), California Air Resources Board, and AAA of Southern California
- Electric Transportation Applications (lead organization), Arizona Public Service, Potomac Electric Power Company, Salt River Project, and Underwriters Laboratory.

The Program's mission is to document the commercial viability of electric vehicles in fleet operations. The Program is accomplishing this by encouraging the purchase and use of electric vehicles through the evaluation and dissemination of performance and field testing results. The information is targeted towards fleet managers, policy makers, regulators, and technicians. Today, only the newest generation of commercially available electric vehicles are being tested, and the three types of testing performed are:

- Baseline performance testing, including initial performance and periodic checks
- Fleet testing, including commercial viability as a day-to-day fleet vehicle and user acceptance issues
- Reliability testing, including accelerated vehicle mileage (100+ miles per day), life-cycle performance of components and subsystems, and vehicle support requirements.

**Baseline Performance/EV America Testing**

Electric Transportation Applications, in conjunction with EV America, vehicle manufacturers, DOE, and other electric utility groups, developed the original baseline performance testing methodology. Since testing began in 1994, the baseline performance testing has been performed according to the testing procedures. In addition, test vehicles must meet minimum qualification standards before being accepted for testing. These standards and procedures are intended to allow vehicle-to-vehicle and year-to-year comparisons of test results. The baseline performance testing methodology is not a static set of test procedures - they have evolved as the vehicle technology has advanced. This testing helps the potential purchaser of electric vehicles to have greater confidence that vehicle performance will be met if a vehicle passes the baseline performance tests. Table 1 provides a summary of the 16 vehicles that have completed the baseline performance testing at the end of 1997. During 1998, several additional models of the newest generation of electric vehicles, from original equipment manufacturers, will also be baseline performance tested. The 1996 and 1997 models tested, and the 1998 models to be tested, represent the most sophisticated electric vehicle technology available, or soon to be available, in the United States.

The test results indicate that vehicle performance has improved each year. Figures 1 and 2 show the testing results for the Driving Cycle range test and the 0 to 50 mph Acceleration tests. The Driving Cycle range test is performed in accordance with the Society of Automotive Engineers (SAE) test standard J1634, and the Acceleration test depicted is conducted at a 50% state-of-charge. The Driving Cycle testing (Figure 1) generally shows an annual increase in range when looking at individual test results. The vehicle with the longest Driving Cycle test results to date continues to be the 1995 Solectria Force sedan with a nickel metal-hydride battery pack. However, some of the 1996 and 1997 test vehicles have also exceeded the range goal of 60 miles with less expensive lead-acid battery packs and with significantly higher vehicle payloads. In one case (Chevrolet S-10), the payload is double that of the Force.

**Table 1.** Testing results for vehicles baseline performance (EV America) tested 1994 through 1997. Acceleration results are in seconds, and maximum speed is in miles per hour.

| Vehicle | Range tests (miles) @45 mph | @60 mph | SAE J1634 | Acceleration 0 to 50 mph | Max. speed | Battery Manufacturer |
|---|---|---|---|---|---|---|
| 1997 test vehicles | | | | | | |
| Chevrolet S-10 | 60 | 39 | 44 | 10.4 | 69 | Delphi |
| Ford Ranger | 87 | 58 | 65 | 12.3 | 75 | Delphi |
| 1996 test vehicles | | | | | | |
| GM EV 1 | 135 | 89 | 78 | 6.7 | 80 | Delphi |
| Toyota RAV4 (lead) | 82 | 55 | 68 | 13.3 | 78 | Matsushita |
| 1995 test vehicles | | | | | | |
| Solectria E-10 | 81 | 50 | 55 | 17.4 | 68 | Hawker |
| Solectria Force | 106 | 71 | 85 | 18.5 | 70 | Ovonic |
| Baker pickup | 61 | 32 | 57 | 14.9 | 71 | Ovonic |
| 1994 test vehicles | | | | | | |
| Solectria S-10 | 73 | 40 | 58 | 21.7 | 66 | Hawker |
| Solectria Force | 50 | 27 | 45 | 21.5 | 70 | Hawker |
| US Electricar pickup | 71 | 47 | 69 | 20.1 | 71 | Hawker |
| US Electricar Sedan | 59 | 42 | 46 | 16.2 | 81 | Hawker |
| Bat Ranger | 55 | 44 | 21 | Failed | failed | Trojan |
| Bat Metro | 88 | 52 | 50 | 26.0 | 67 | Trojan |
| Bat Metro | 47 | 40 | 38 | 16.5 | 81 | Optima |
| Dodge Caravan | 86 | 57 | 51 | 33.9 | 62 | Picher |
| Unique pickup | 54 | 38 | 43 | 30.3 | 70 | Optima |

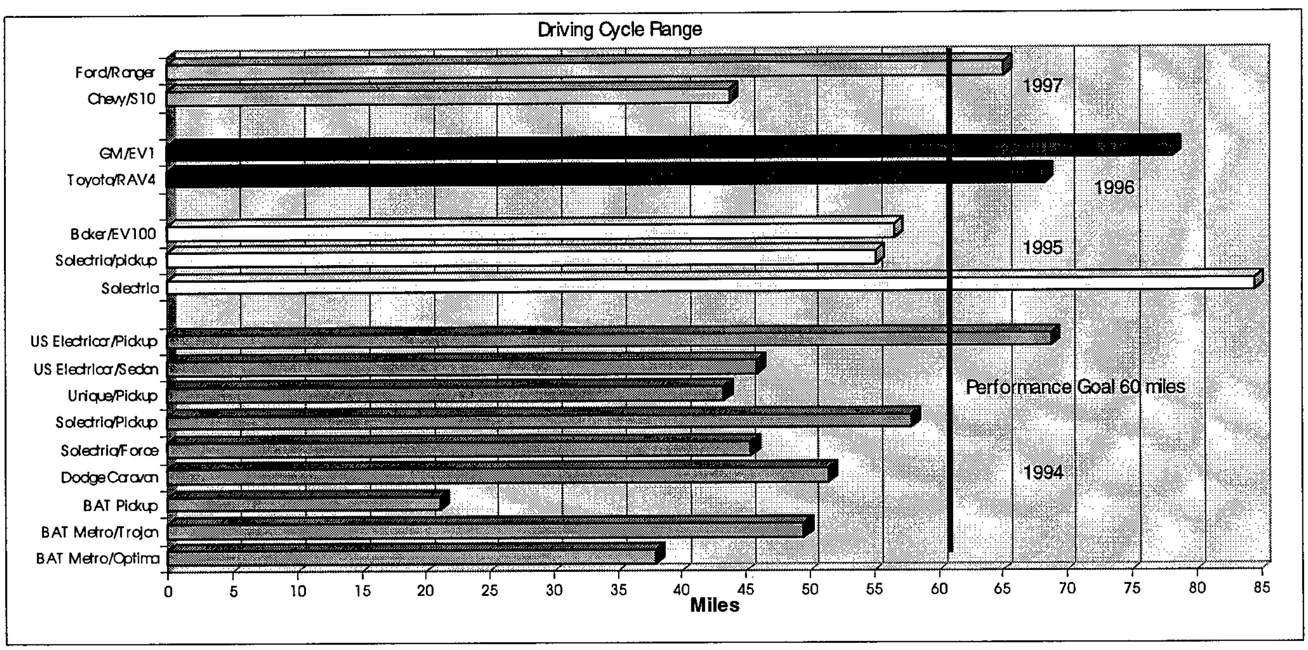


**Figure 1.** Baseline performance Driving Cycle range test results for vehicles tested 1994 through 1997.

The Acceleration 0 to 50 mph test results (Figure 2) indicate a year-to-year decrease in the time required to accelerate to 50 mph at a 50% state-of-charge. Both of the lead-acid equipped 1997 test vehicles (Ford Ranger and Chevrolet S-10) easily exceeded the acceleration goal of 13.5 seconds. The acceleration testing results for these two pickups are likely the result of advanced vehicle components, especially given their high payload capacities and overall vehicle weights compared to some of the earlier products from vehicle converters. The fastest accelerating vehicle to date continues to be the General Motors EV1. The EV1 has a 0 - 50 mph acceleration time of 6.7 seconds at 50% state-of-charge.

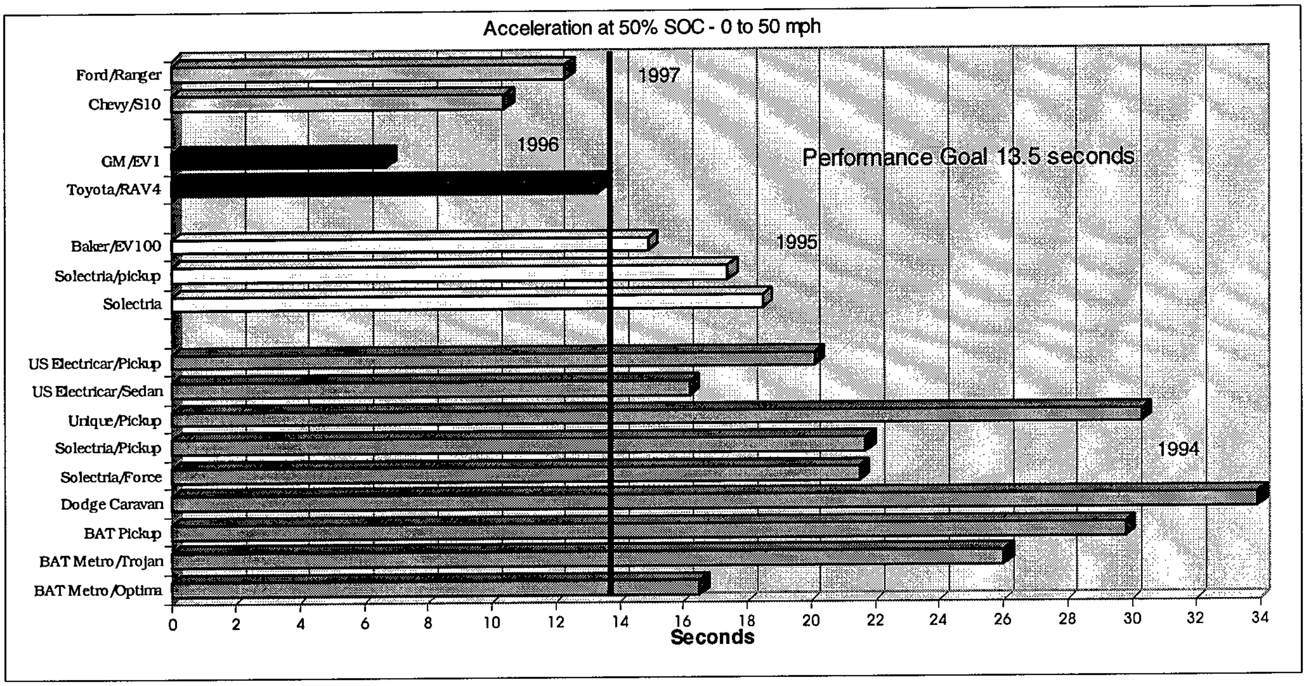


**Figure 2**. Baseline performance acceleration test results for the 16 vehicles tested 1994 through 1997.

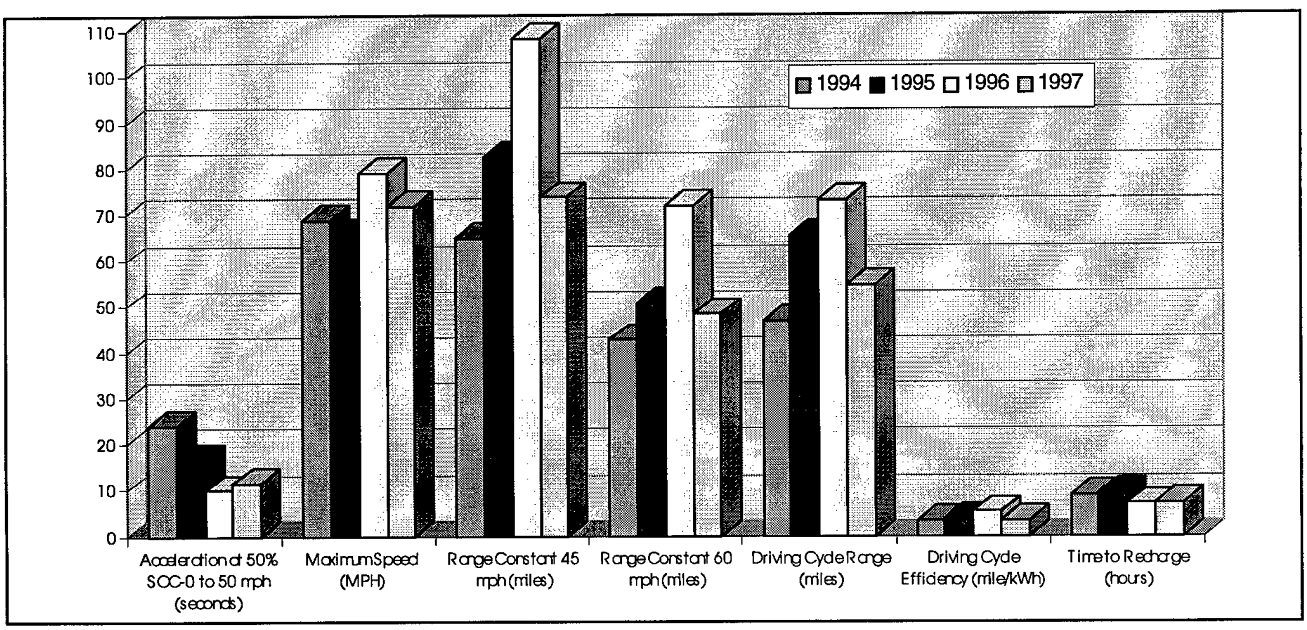


**Figure 3**. Average annual results for vehicles baseline performance tested 1994 through 1997.

Figure 3 captures the average annual results for seven of the baseline performance tests. The test results include all 16 vehicles tested from 1994 through 1997. The average test results for the years

1994, 1995, and 1996 all show annual improvements with the exception of the maximum speed test results from 1994 to 1995, when there was a less than 3 mph drop-off in the average maximum speed. Additionally, the time to recharge was slightly longer during 1995 than 1994, but this is primarily due to the higher energy capacity of the nickel metal-hydride battery in the Solectria Force. The two vehicles tested during 1997 do not continue this trend of increased performance testing results. However, it should be recognized that these two vehicles (Chevrolet S-10 and Ford Ranger) are the first product offerings targeted for utility fleet use from original equipment manufacturers (OEM). The S-10 and the Ranger have OEM-backed vehicle warranties as well as the payloads required for utility fleet applications. It is anticipated that the lead-acid battery packs initially provided with the S-10 and Ranger will be replaced and the vehicles will then be offered with more advanced nickel metal-hydride batteries.

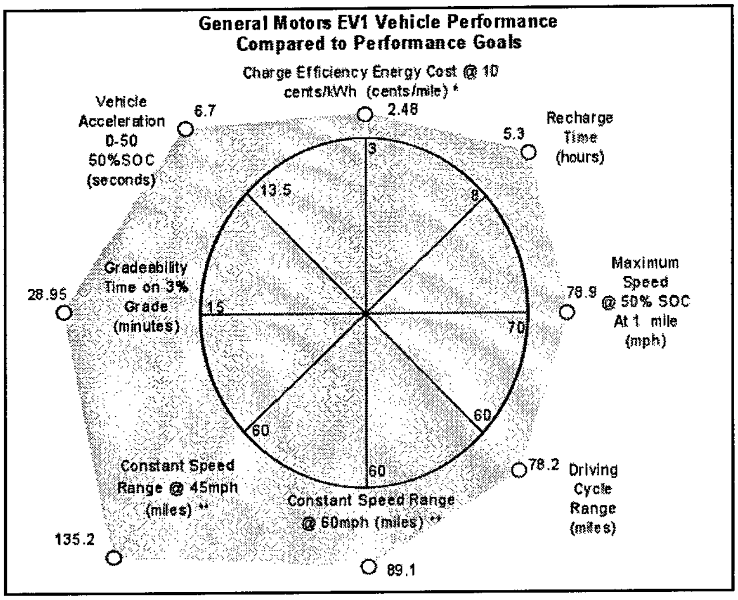


**Figure 4**. General Motors EV1 baseline performance (EV America) test results compared to performance goals.

The development of the baseline performance testing procedures included the development of the performance goals. These goals were developed based on the mission requirements for utility fleet vehicles. The baseline performance test results for the Ford Ranger, Chevrolet S-10 and General Motors EV1 are graphed against the performance goals for eight tests (Figures 4, 5 and 6). If the test results for a performance goal are exceeded, they are plotted outside of the spider graph. For instance, the EV1 exceeded all of the performance goals and, thus, the gray area outside of the spiderchart for the EV1 indicates that all of the performance goals were exceeded. The EV1 is the only vehicle to date that has exceeded all of the performance goals for the baseline performance tests. Both the Ford Ranger (Figure 5) and the Chevrolet S-10 (Figure 6) exceeded several of the baseline performance goals.

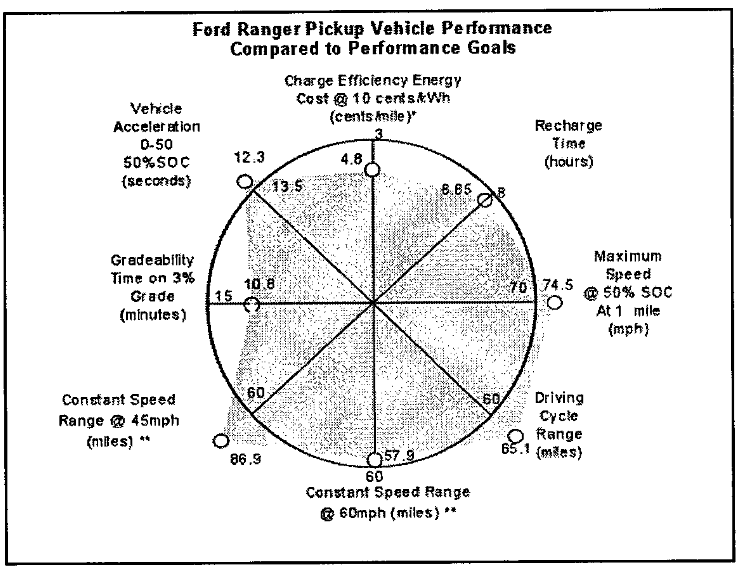


**Figure 5**. Ford Ranger baseline performance (EV America) test results compared to performance goals.

## Fleet Operations

The Program's primary fleet operations focus is on new electric vehicles produced by the OEMs. In support of this focus, the program and its qualified vehicle testing partners have acquired 15 Chevrolet S-10 pickups. Five of the S-10 pickups are being tested in the accelerated reliability mode, with the goal of obtaining 100 miles per vehicle per day. The other 10 vehicles are used in standard fleet operations. Unfortunately, several of the S-10s have had lead-acid module failures requiring the replacement of whole packs, while two of the S-10 pickups in the accelerated reliability test mode have performed very well. The two S-10s in the accelerated reliability mode have each accumulated over 9,000 miles in approximately 3 months of driving, with no battery pack problems. The coincidences of failures and successes suggest that the S-10s must not be allowed to sit at the dealers upon delivery, that they must be broken in quickly and properly, and driven daily. Some of the vehicles experiencing module failures may have sat for a period of time either in transit, preparation, or at the final user destination. The S-10s appear to be good vehicles but are limited by the battery technology and amount of onboard energy stored. General Motors has announced that the S-10, as well as the EV1, will be equipped with GM Ovonic nickel metal-hydride batteries. Use of a S-10 with a nickel metal-hydride battery outside of the Field Operations Program has shown a range of about 80 miles, approximately double that of the lead-acid equipped S-10.

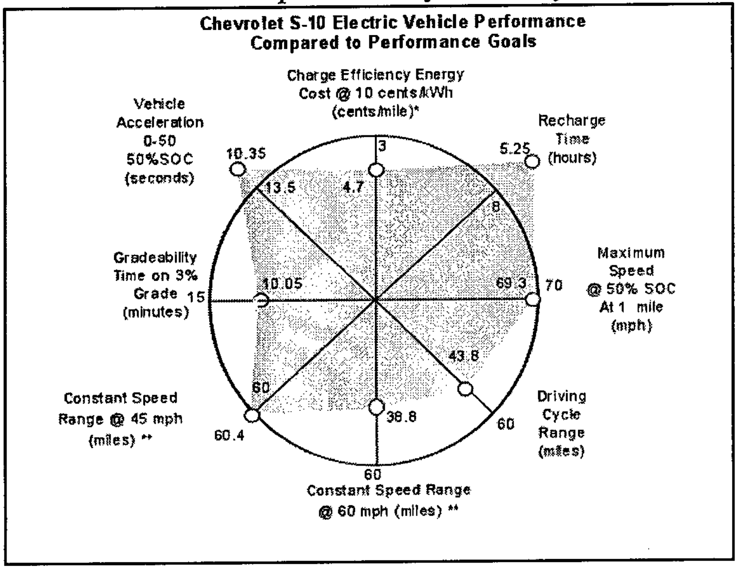


**Figure 6.** Chevrolet S-10 baseline performance (EV America) test results compared to performance goals.

A Chrysler EPIC minivan is also undergoing accelerated reliability testing, with the 100 miles per day goal. Problems with the original lead-acid battery technology used with this vehicle have made mileage accumulation difficult. The EPIC's original battery pack was replaced twice before the vehicle achieved 3,000 miles. Chrysler has announced that the EPIC will be available with a nickel metal-hydride battery from Saft during 1998. This technology should provide greater onboard energy storage and greater reliability.

The Field Operations Program and its qualified vehicle test partners have ordered a total of 53 new electric Ford Rangers and Toyota RAV4s. These 53 vehicles will be operated under a variety of circumstances at the qualified vehicle testers' locations (Table 2).

**Table 2.** Electric Ford Rangers and Toyota RAV4s ordered by the Field Operations Program and the Qualified Vehicle Testers. The 53 vehicles will be placed in normal fleet applications and tested in accelerated reliability modes (100 miles per day).

| | RAV4 Fleet | RAV4 Reliability | Ranger Fleet | Ranger Reliability Level II Charging | Ranger Reliability Level III Charging | Totals |
|---|---|---|---|---|---|---|
| Arizona Public Service | | | 2 | | 2 | 4 |
| Potomac Electric Power | 10 | 2 | 5 | 2 | | 19 |
| Salt River Project | | | 1 | | | 1 |
| Southern California Edison | 10 | 3 | 10 | 3 | 3 | 29 |
| Totals | 20 | 5 | 18 | 5 | 5 | 53 |

## Infrastructure Development

In the United States, there is no single national program for electric vehicle infrastructure development; however, there are several broad-based cooperative efforts, mostly industry-driven with government playing a supporting role. Some of these groups are attempting to establish regional, state, or local infrastructure for electric vehicles. The organization leading the development of national infrastructure standards in the United States is the Infrastructure Working Council (IWC). The IWC was established by the Electric Power Research Institute (EPRI) in 1991, and it is a collaborative effort of electric utilities and the automobile industry. The IWC is also supported by the Federal government (through DOE), various industry associations (Edison Electric Institute, Electric Vehicle Association of the Americas, Electric Transportation Coalition), and manufacturer groups (e.g., National Electrical Manufacturers Association).

The IWC's activities include the development of consensus recommendations to industry, proposing standards and protocols, supporting the development of pre-production prototypes of charging and protection equipment, carrying out independent testing of components such as connectors, and performing public outreach and education through print and national infrastructure conferences. The IWC comprises five working committees (Figure 7), each responsible for specific areas.

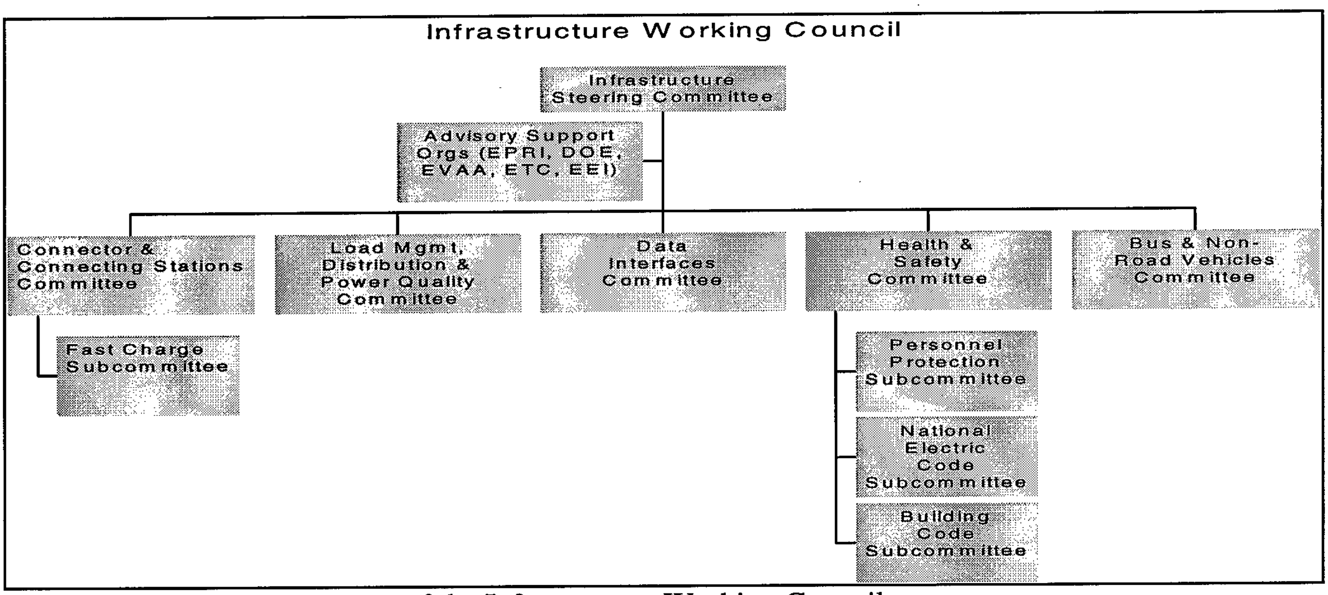


**Figure 7**. Committee structure of the Infrastructure Working Council.

Because a complete discussion of each committee's activities is beyond the scope of this paper, only a sample of the Connector and Connecting Stations Committee's (C&CS) activities is discussed below. A complete description of the IWC's activities can be found at the web site: http://www.epri.com/csg/trans/iwc/

The C&CS mission is to develop standard physical and electrical configurations for the transfer of energy and information at the utility/vehicle interface. Some of the specific accomplishments include:

- Standard inductive charging connector defined and published as SAE J1773
- Standard conductive charging connector defined as SAE J1772

- Pin and sleeve version extensively tested
- Revised butt connector version to be tested
- Standard charging levels 1, 2 and 3 defined
  - *Level 1*: cord and plug connected, most common grounded outlet (120VAC, 15A)
  - *Level 2*: permanently wired (fixed location) equipment up to 240VAC, 60A, 14.4 kW
  - *Level 3*: fixed equipment rated at >14.4 kW

Some of the other infrastructure activities supported by the IWC include:

- Emergency responder training program for California (sponsored by auto makers)
- Special electricity rates for charging (as low as $0.041/kWh)
- Arizona establishes Clean Air Fund, tax credits to small businesses that install charging stations, electric vehicle exemptions from special fees and use of HOV lanes
- Oklahoma gives 50% tax credit for electric vehicles

**Summary**

The performance characteristics of electric vehicles are continuing to improve. The vehicles that were baseline performance tested have shown specific improvements in many of the individual performance tests and they are now backed by OEM warranties. Unfortunately, the Program's initial experience with new vehicles in fleet applications and in accelerated reliability testing has not been completely favorable. The S-10's and EPIC's ranges and reliability are limited by the current lead-acid battery technologies, but both of these products will be offered in the near future with advanced nickel metal-hydride battery packs. The Ford Ranger will initially use a different lead-acid battery and the Toyota RAV4 is using a nickel metal-hydride battery pack.

Infrastructure development by the IWC continues in many different areas, including charging connections, data interfacing and load management, as well as in personnel health and safety support. Infrastructure development is also occurring at the state and local levels with revisions to building and electrical codes, and the installation of public charge stations.

The Department of Energy, through the Field Operations Program, continues to support the above efforts in addition to purchasing the newest generation of electric vehicles for testing and evaluation. The Program will continue to disseminate testing results via reports and the Program's web page in support of well-informed electric vehicle purchase decisions. However, successful fleet deployment will only occur when electric vehicles are matched to duty cycles, and the fleet managers and operators have confidence that the electric vehicles they purchase are fully capable of meeting their performance expectations.

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Report Number (14) INEEL/CON--98-00224

CONF-980619--

Publ. Date (11) 199803

Sponsor Code (18) DOE/EE, XF

UC Category (19) UC-1200, DOE/ER

DOE